

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization  
International Bureau



(43) International Publication Date  
17 March 2005 (17.03.2005)

PCT

(10) International Publication Number  
**WO 2005/024171 A3**

(51) International Patent Classification:  
**E21B 43/10** (2006.01)

(21) International Application Number:

PCT/US2004/028889

(22) International Filing Date:

7 September 2004 (07.09.2004)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:

60/500,435 5 September 2003 (05.09.2003) US

60/585,370 2 July 2004 (02.07.2004) US

60/600,679 11 August 2004 (11.08.2004) US

(71) Applicant (for all designated States except US): **EN-  
VENTURE GLOBAL TECHNOLOGY, LLC** [US/US];  
16200 A Park Row, Houston, TX 77084 (US).

(72) Inventors; and

(75) Inventors/Applicants (for US only): **SHUSTER, Mark**  
[US/US]; 19115 Prospect Ridge Lane, Houston, TX 77094  
(US). **GRAY, Malcolm** [US/US]; 9025 Briar Forest, Hous-  
ton, Texas 77024 (US). **GRINBERG, Grigoriy** [US/US];  
4758 Mount Airy, Sylvania, OH 43560 (US). **SHADE,**  
**Matt** [US/US]; 12831 Wendover Drive, Plymouth, MI  
48170 (US). **PETLYUK, Alla** [US/US]; 933 Trellis Lane,  
West Chester, PA 19382 (US). **COSTA, Scott** [US/US];  
25614 Broadcrest Court, Katy, TX 77494 (US).

(74) Agents: **HAYNES AND BOONE LLP** et al.; 901 Main  
Street, Suite 3100, Haynes and Boone, LLP, Dallas, TX  
75202 (US).

(81) Designated States (unless otherwise indicated, for every  
kind of national protection available): AE, AG, AL, AM,  
AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN,  
CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI,  
GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE,  
KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD,  
MG, MK, MN, MW, MX, MZ, NA, NI, NO, NZ, OM, PG,  
PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM,  
TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM,  
ZW.

(84) Designated States (unless otherwise indicated, for every  
kind of regional protection available): ARIPO (BW, GH,  
GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM,  
ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM),  
European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI,  
FR, GB, GR, HU, IE, IT, LU, MC, NL, PL, PT, RO, SE,  
SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN,  
GQ, GW, ML, MR, NE, SN, TD, TG).

Declaration under Rule 4.17:

— of inventorship (Rule 4.17(iv))

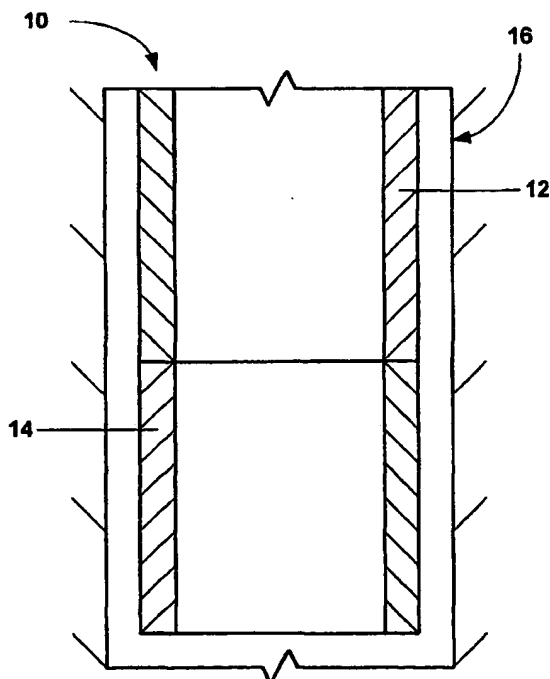
Published:

— with international search report

— with amended claims

[Continued on next page]

(54) Title: **EXPANDABLE TUBULAR**



(57) Abstract: A system for reducing the coeffi-  
cient of friction between an expansion device (20)  
and a tubular member (14).

WO 2005/024171 A3



(88) Date of publication of the International search report:

16 March 2006

Date of publication of the amended claims:

22 June 2006

*For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.*

**AMENDED CLAIMS**

received by the International Bureau on 13 January 2006 (13.01.2006)

1-672. (Canceled)

673. (Original) An expandable tubular member, comprising:

a tubular body;

wherein a yield point of an inner tubular portion of the tubular body is less than a yield point of an outer tubular portion of the tubular body.

674. (Original) The expandable tubular member of claim 673, wherein the yield point of the inner tubular portion of the tubular body varies as a function of the radial position within the tubular body.

675-676. (Canceled)

677. (Original) The expandable tubular member of claim 673, wherein the yield point of the outer tubular portion of the tubular body varies as a function of the radial position within the tubular body.

678-679. (Canceled)

680. (Original) The expandable tubular member of claim 673,

wherein the yield point of the inner tubular portion of the tubular body varies as a function of the radial position within the tubular body; and

wherein the yield point of the outer tubular portion of the tubular body varies as a function of the radial position within the tubular body.

681-728. (Canceled)

729. (Original) A method of manufacturing an expandable tubular member, comprising:

providing a tubular member;

heat treating the tubular member; and

quenching the tubular member;

wherein following the quenching, the tubular member comprises a microstructure comprising a hard phase structure and a soft phase structure.

730-732. (Canceled)

733. (Original) The method of claim 729, wherein the provided tubular member comprises a microstructure comprising one or more of the following: martensite, pearlite, vanadium carbide, nickel carbide, or titanium carbide.

734. (Original) The method of claim 729, wherein the provided tubular member comprises a microstructure comprising one or more of the following: pearlite or pearlite striation.

735. (Original) The method of claim 729, wherein the provided tubular member comprises a microstructure comprising one or more of the following: grain pearlite, widmanstätten martensite, vanadium carbide, nickel carbide, or titanium carbide.

736-737. (Canceled)

738. (Original) The method of claim 729, wherein following the quenching, the tubular member comprises a microstructure comprising one or more of the following: ferrite, grain pearlite, or martensite.

739. (Original) The method of claim 729, wherein following the quenching, the tubular member comprises a microstructure comprising one or more of the following: ferrite, martensite, or bainite.

740. (Original) The method of claim 729, wherein following the quenching, the tubular member comprises a microstructure comprising one or more of the following: bainite, pearlite, or ferrite.

741-743. (Canceled)

744. (Currently Amended) A method of manufacturing an expandable tubular member, comprising:

- providing a tubular member;
- heat treating the tubular member;
- quenching the tubular member;
- positioning the quenched tubular member within a preexisting structure; and
- radially expanding and plastically deforming the tubular member within the

preexisting structure,  
wherein following the quenching, the tubular member comprises a microstructure comprising a hard phase structure and a soft phase structure.

745-757. (Canceled)

758. (Original) A system for radially expanding and plastically deforming a tubular member, comprising:

an expansion device positioned in the tubular member; and  
wherein the coefficient of friction between the expansion device and the tubular member during radial expansion and plastic deformation is less than 0.08.

759. (Canceled)

760. (Original) The system of claim 758, additionally comprising:  
lubricant between the tubular member and the expansion device.

761-776. (Canceled)

777. (Original) The system of claim 758, additionally comprising:  
a coating on the expansion device.

778. (Canceled)

779. (Original) The system of claim 758, additionally comprising:  
a coating on the tubular member.

780-797. (Canceled)

798. (Original) The system of claim 758, wherein lubricant is injected through at least a portion of the expansion device between the tubular member and the expansion device when a predetermined pressure is met.

799. (Original) The system of claim 758, wherein lubricant is injected through at least two portions of the expansion device between the tubular member and the expansion device at two different pressures.

**800. (Original) The system of claim 758, wherein the expansion device comprises:**

- a tapered portion with an outer surface;**
- internal flow passage in the tapered portion; and**
- at least one circumferential groove having a first edge and a second edge having with a sliding angle on the outer surface of the tapered portion fluidically coupled to the internal flow passage for receiving lubricant during radial expansion and plastic deformation of the tubular member;**
- wherein the sliding angle is less than or equal to 30 degrees.**

**801. (Original) The system of claim 758, wherein the expansion device comprises:**

- a tapered portion with an outer surface;**
- internal flow passage in the tapered portion; and**
- at least one circumferential groove having a first edge and a second edge having with a sliding angle on the outer surface of the tapered portion fluidically coupled to the internal flow passage for receiving lubricant during radial expansion and plastic deformation of the tubular member;**
- wherein the sliding angle is less than or equal to 10 degrees.**

**802. (Canceled)**

**803. (Original) The system of claim 758, wherein the expansion device comprises:**

- a tapered portion having a tapered faceted polygonal outer expansion surface.**

**804. (Original) The system of claim 758, wherein the tubular member has a non-uniform wall thickness and the expansion device comprises:**

- a tapered portion having a tapered faceted polygonal outer expansion surface.**

**805. (Original) The system of claim 758, wherein lubricant is stored in a reservoir with electrodes that are electrically coupled a capacitor in the expansion device and is injected through at least a portion of the expansion device between the tubular member and the expansion device when the capacitors discharges.**

**806–1232. (Canceled)**

**1233. (Original) A lubricant delivery assembly for radially expanding and plastically deforming a tubular member, comprising:**

- an expansion device having a tapered portion with an outer surface, at least one reservoir for housing a lubricant, at least one circumferential groove on the outer surface fluidly connected to the reservoir, and
- a lubricant injection mechanism to force lubricant into the at least one circumferential groove while radially expanding and plastically deforming the tubular member when a predetermined lubricant pressure is reached.

1234. (Original) The lubricant delivery assembly of claim 1233, wherein lubricant is stored in a reservoir with a magnetic coil in the expansion device and is injected through at least a portion of the expansion device between the tubular member and the expansion device when current runs through the magnetic coil.

1235. (Original) The lubricant delivery assembly of claim 1233, wherein lubricant is stored in a reservoir in the lubrication device and injected through at least a portion of the expansion device between the tubular member and the expansion device when vaporized.

1235. (Original) The lubricant delivery assembly of claim 1233, wherein lubricant is stored in a reservoir with electrodes that are electrically coupled a capacitor in the expansion device and is injected through at least a portion of the expansion device between the tubular member and the expansion device when the capacitors discharges.

1236–1263. (Canceled)

1264. (Original) A system for radially expanding and plastically deforming a tubular member having a non-uniform wall thickness, comprising:  
an expansion device having one or more expansion surfaces and a tapered portion having a tapered faceted polygonal outer expansion surface in the interior surface of the tubular member.

1265. (Original) The system of claim 1264, additionally comprising:  
lubricant between the tubular member and the expansion device.

1266–1281. (Canceled)

1282. (Original) The system of claim 1264, additionally comprising:  
a coating on the expansion device.

1283. (Canceled)

1284. (Currently Amended) A system for radially expanding and plastically deforming a tubular member having a non-uniform wall thickness, comprising:

- an expansion device having one or more expansion surfaces and a tapered portion having a tapered faceted polygonal outer expansion surface in the interior surface of the tubular member; and
- a coating on the tubular member.

1285–1301. (Canceled)

1302. (Original) The system of claim 1264, wherein lubricant is injected through at least a portion of the expansion device between the tubular member and the expansion device.

1303. (Currently Amended) A system for radially expanding and plastically deforming a tubular member having a non-uniform wall thickness, comprising:

- an expansion device having one or more expansion surfaces and a tapered portion having a tapered faceted polygonal outer expansion surface in the interior surface of the tubular member,
- wherein lubricant is injected through at least a portion of the expansion device between the tubular member and the expansion device when a predetermined lubricant pressure is met.

1303. (Currently Amended) A system for radially expanding and plastically deforming a tubular member having a non-uniform wall thickness, comprising:

- an expansion device having one or more expansion surfaces and a tapered portion having a tapered faceted polygonal outer expansion surface in the interior surface of the tubular member,
- wherein lubricant is injected through at least a portion of the expansion device between the tubular member and the expansion device when a predetermined lubricant pressure is met.

1304. (Currently Amended) A system for radially expanding and plastically deforming a tubular member having a non-uniform wall thickness, comprising:

- an expansion device having one or more expansion surfaces and a tapered portion having a tapered faceted polygonal outer expansion surface in the interior



surface of the tubular member,  
wherein lubricant is injected through at least two portions of the expansion device  
between the tubular member and the expansion device at two different  
pressures.

1305. (Original) The system of claim 1264, wherein the expansion device comprises:  
a tapered portion with an outer surface;  
internal flow passage in the tapered portion; and  
at least one circumferential groove having a first edge and a second edge having  
with a sliding angle on the outer surface of the tapered portion fluidically  
coupled to the internal flow passage for receiving lubricant during radial  
expansion and plastic deformation of the tubular member;  
wherein the sliding angle is less than or equal to 30 degrees.

1306. (Original) The system of claim 1264, wherein the expansion device comprises:  
a tapered portion with an outer surface;  
internal flow passage in the tapered portion; and  
at least one circumferential groove having a first edge and a second edge having  
with a sliding angle on the outer surface of the tapered portion fluidically  
coupled to the internal flow passage for receiving lubricant during radial  
expansion and plastic deformation of the tubular member;  
wherein the sliding angle is less than or equal to 10 degrees.

1307. (Canceled)

1308. (Currently Amended) A system for radially expanding and plastically deforming a  
tubular member having a non-uniform wall thickness, comprising:  
an expansion device having one or more expansion surfaces and a tapered portion  
having a tapered faceted polygonal outer expansion surface in the interior  
surface of the tubular member,  
wherein lubricant is stored in a reservoir with electrodes that are electrically coupled  
a capacitor in the expansion device and is injected through at least a portion  
of the expansion device between the tubular member and the expansion  
device when the capacitors discharges.

1309-1312. (Canceled)

**1313. (Original)** A method of radially expanding and plastically deforming a tubular member having a non-uniform wall thickness, comprising:  
positioning an expansion device having one or more expansion surfaces and a tapered portion having a tapered faceted polygonal outer expansion surface in the interior surface of the tubular member; and  
displacing the expansion device relative to the tubular member to radially expand and plastically deform the tubular member.

**1314. (Original)** The method of claim 1313, additionally comprising:  
injecting lubricant between the tubular member and the expansion device.

**1315–1330. (Canceled)**

**1331. (Original)** The method of claim 1313, additionally comprising  
applying a coating on the expansion device prior to positioning within the tubular member.

**1332. (Canceled)**

**1333. (Currently Amended)** A method of radially expanding and plastically deforming a tubular member having a non-uniform wall thickness, comprising:  
positioning an expansion device having one or more expansion surfaces and a tapered portion having a tapered faceted polygonal outer expansion surface in the interior surface of the tubular member;  
displacing the expansion device relative to the tubular member to radially expand and plastically deform the tubular member; and  
applying a coating on the tubular member prior to positioning the expansion device within the tubular member.

**1334–1346. (Canceled)**

**1347. (Currently Amended)** A method of radially expanding and plastically deforming a tubular member having a non-uniform wall thickness, comprising:  
positioning an expansion device having one or more expansion surfaces and a tapered portion having a tapered faceted polygonal outer expansion surface in the interior surface of the tubular member; and  
displacing the expansion device relative to the tubular member to radially expand and

plastically deform the tubular member,  
wherein the expansion device comprises a processed finish.

1348. (Currently Amended) A method of radially expanding and plastically deforming a tubular member having a non-uniform wall thickness, comprising:  
positioning an expansion device having one or more expansion surfaces and a tapered portion having a tapered faceted polygonal outer expansion surface in the interior surface of the tubular member; and  
displacing the expansion device relative to the tubular member to radially expand and plastically deform the tubular member,  
wherein the expansion device has a relatively smooth surface roughness.

1349. (Currently Amended) A method of radially expanding and plastically deforming a tubular member having a non-uniform wall thickness, comprising:  
positioning an expansion device having one or more expansion surfaces and a tapered portion having a tapered faceted polygonal outer expansion surface in the interior surface of the tubular member; and  
displacing the expansion device relative to the tubular member to radially expand and plastically deform the tubular member,  
wherein the expansion device has a relatively smooth surface roughness and includes relatively evenly space oil pockets.

1350. (Canceled)

1351. (Original) The method of claim 1313, additionally comprising:  
injecting lubricant through at least a portion of the expansion device between the tubular member and the expansion device.

1352. (Currently Amended) A method of radially expanding and plastically deforming a tubular member having a non-uniform wall thickness, comprising:  
positioning an expansion device having one or more expansion surfaces and a tapered portion having a tapered faceted polygonal outer expansion surface in the interior surface of the tubular member;  
displacing the expansion device relative to the tubular member to radially expand and plastically deform the tubular member; and  
injecting lubricant through at least a portion of the expansion device between the tubular member and the expansion device when a predetermined lubricant

pressure is met.

**1353. (Currently Amended)** A method of radially expanding and plastically deforming a tubular member having a non-uniform wall thickness, comprising:

- positioning an expansion device having one or more expansion surfaces and a tapered portion having a tapered faceted polygonal outer expansion surface in the interior surface of the tubular member;
- displacing the expansion device relative to the tubular member to radially expand and plastically deform the tubular member; and
- injecting lubricant through at least two portions of the expansion device between the tubular member and the expansion device at two different pressures.

**1354. (Original)** The method of claim 1313, wherein the expansion device, comprises:

- a tapered portion with an outer surface;
- internal flow passage in the tapered portion; and
- at least one circumferential groove having a first edge and a second edge having with a sliding angle on the outer surface of the tapered portion fluidly coupled to the internal flow passage for receiving lubricant during radial expansion and plastic deformation of the tubular member;

wherein the sliding angle is less than or equal to 30 degrees.

**1355. (Original)** The method of claim 1313, wherein the expansion device, comprises:

- a tapered portion with an outer surface;
- internal flow passage in the tapered portion; and
- at least one circumferential groove having a first edge and a second edge having with a sliding angle on the outer surface of the tapered portion fluidly coupled to the internal flow passage for receiving lubricant during radial expansion and plastic deformation of the tubular member;

wherein the sliding angle is less than or equal to 10 degrees.

**1356. (Canceled)**

**1357. (Currently Amended)** A method of radially expanding and plastically deforming a tubular member having a non-uniform wall thickness, comprising:

- positioning an expansion device having one or more expansion surfaces and a tapered portion having a tapered faceted polygonal outer expansion surface in the interior surface of the tubular member; and

displacing the expansion device relative to the tubular member to radially expand and plastically deform the tubular member,  
wherein lubricant is stored in a reservoir with electrodes that are electrically coupled a capacitor in the expansion device; additionally comprising:  
charging the capacitor;  
discharging the capacitor through the electrodes; and  
injecting the lubricant through at least a portion of the expansion device between the tubular member and the expansion device when the capacitors discharges.

1358-1369. (Canceled)